5th Workshop of the

Decay Data Evaluation Project

Agenda & Abstracts

DDEP-2014

http://ddep14.nipne.ro

October 6-8, 2014

National Physics Library, Bucharest-Magurele, Romania

Organizers:

- Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Romania
- Decay Data Evaluation Project (DDEP)

In cooperation with:

- International Atomic Energy Agency (IAEA)

With the support of:

- Institute of Atomic Physics (IFA), Romania
- Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA), France

Scientific committee (*alphabetical order*)

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Eng. Thierry BRANGER (CEA Saclay, LIST/DM2I/LNHB, France)
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Ec. Mihaela CIATLOS (IFIN-HH, DRMR, Romania)
Ec. Alexandru POPESCU (Financial Manager of IFIN-HH, Romania)

Introduction

The goal of the Decay Data Evaluation Project (DDEP) International Cooperation (*http://www.nucleide.org/DDEP.htm*) is to produce evaluations of nuclear data for radionuclides used in nuclear physics, applied research and in detector calibration.

Since its genesis, it has produced about 215 data evaluations from an initial list of about 250 radionuclides; these data are used in the nuclear physics research, nuclear power industry, nuclear medicine, radiation protection, processing and storage of nuclear waste, radionuclide metrology and, in particular, in the calibration of gamma-ray detectors.

The DDEP collaboration had its First Workshop of Training Sessions in Saclay, France, March 6-10, 2006. The 2nd workshop was successfully organized by the Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), in Bucharest, Romania, May 12-14, 2008, *http://www.nipne.ro/ddep2008/*.

Now, the 5th Workshop of the Decay Data Evaluation Project (DDEP-2014) is organized again by IFIN-HH and DDEP, but in a new modern location – The National Physics Library, in Bucharest-Magurele, Romania, during the period October 6-8, 2014. The workshop is organized in cooperation with the International Atomic Energy Agency (IAEA), and with the support of the Institute of Atomic Physics (IFA) and the Commissariat à l'énergie atomique et aux énergies alternatives, CEA Saclay, France. The web page of the workshop is:

http://ddep14.nipne.ro/

The main objectives of the workshop are the following:

- To disseminate the results obtained in the joint research project IFA Romania-CEA France no. C2-05/2012: "Creation of national standards for some emerging pharmaceutical radionuclides to ensure the radioprotection of patients and medical staffs", http://proiecte.nipne.ro/ifa-cea/3-projects.html.
- To revise the current nuclear decay data evaluation effort and plan a strategy to fulfill the goal of the collaboration, including the implementation of new approaches to data evaluation procedures and application of new computer software.
- To present the DDEP current data evaluation methods and procedures as a training and to attract new members in this collaboration.
- To help the participants in their nuclear data evaluations and related scientific work.

The topics of the workshop are:

- The results obtained in the Joint Research Project IFA Romania – CEA France no. C2-05/2012, by IFIN-HH, DRMR/Radionuclide Metrology Laboratory and CEA/LIST, LNE-Laboratoire National Henri Becquerel
- Nuclear Decay Data: theory, experimental determination, applications
- Evaluation of Nuclear Decay Data: principles, procedures and tools, examples and practical exercises
- International collaborations in the field of nuclear decay data evaluation (DDEP, IAEA, NSDD Evaluators Network and BIPM).

On behalf of the Local Organizing Committee, I address to all the participants a warm welcome at the workshop and I am confident that this scientific event will be a success, interesting and useful for nuclear physicists – especially those working in radionuclide metrology and its applications, chemists, nuclear data evaluators, students and new comers in this field. Especially for the participants coming from abroad, I wish them to enjoy their stay in Bucharest and Magurele. I also invite these colleagues to come back anytime in Romania, as tourists, to discover our beautiful country, and the original traditions and warm hospitality of the Romanian people.

Thank you.

On behalf of the Local Organizing Committee from IFIN-HH,
Dr. Aurelian Luca

AGENDA

Monday, October 6, 2014

08:15-09:30	**Registration of participants**
09:30-10:00	**Welcome to IFIN-HH, Bucharest-Magurele** Prof. Nicolae Victor Zamfir (Director General IFIN-HH), Dr. Maria Sahagia (Head of Radionuclide Metrology Laboratory), Dr. Aurelian Luca (Organizing Committee)
10:00-11:00	**Recent work and results of the Radionuclide Metrology Laboratory from IFIN-HH** Dr. Maria Sahagia (IFIN-HH, Romania)
11:00-11:30	**Radiopharmaceuticals Research Centre – a new facility at Horia Hulubei Institute for Physics and Nuclear Engineering** Dr. Dana Niculae (IFIN-HH, Romania)
11:30-11:50	*Coffee Break*
11:50-12:10	**Improvements of Decay Data in Radioactive Waste Management (MetroRWM) and Naturally Occurring Radioactive Materials (MetroNORM)** Dr. Marie-Martine Bé (CEA/LIST, LNE-LNHB, France)
12:10-12:30	**Nuclear structure and decay data at the IAEA Nuclear Data Section** Dr. Paraskevi Dimitriou (International Atomic Energy Agency, Nuclear Data Section, Austria)
12:30-14:00	*Lunch Break*
14:00-14:20	**Precise measurement of the K-shell internal conversion coefficient for the 88.3-keV M4 transition in ^{127}Te** Dr. Ninel Nica (Cyclotron Institute, Texas A&M University, USA)
14:20-14:40	**Simultaneous production of ^{55}Co, ^{57}Ni and ^{64}Cu for PET imaging** Dr. Zoltan Szucs (Institute for Nuclear Research of the Hungarian Academy of Sciences -ATOMKI, Hungary)
14:40-15:00	*Coffee Break*
15:00-16:00	**Questions, discussions and remarks about the topics of the day**
19:00-22:00	*Workshop Dinner (restaurant)*

Tuesday, October 7, 2014

Special Session: Results of the Joint Research Project IFA Romania-CEA France no. C2-05/2012 (2012-2015)

09:00-09:40 **Presentation of the results obtained in the Joint Research Project IFA Romania-CEA France no. C2-05/2012**
Eng. Thierry Branger (CEA/LIST, LNE-LNHB, France)
and Dr. Aurelian Luca (IFIN-HH, Romania)

09:40-10:20 **Experimental determination of nuclear decay data for ^{177}Lu and ^{186}Re**
Dr. Aurelian Luca (IFIN-HH, Romania)

10:20-10:50 ***Coffee Break***

10:50-11:15 **Evaluation of nuclear decay data from the decay of ^{177}Lu and ^{186}Re**
Dr. Mark A. Kellett (CEA/LIST, LNE-LNHB, France)

11:15-12:00 **Future perspectives of the collaboration between CEA, LNE-LNHB and IFIN-HH, in bilateral and European/international research projects**
Discussion

12:00-13:30 ***Lunch Break***

13:30-14:00 **Experimental study of beta spectra using a semiconductor silicon detector**
Dr. Xavier Mougeot (CEA/LIST, LNE-LNHB, France)

14:00-14:20 **Evaluation of the 1077 keV γ-ray emission probability from ^{68}Ga decay**
Dr. Xiaolong Huang (China Institute of Atomic Energy, China)

14:20-14:35 **Tips and tricks with SAISINUC**
Eng. Christophe Dulieu and Dr. Mark A. Kellett (CEA/LIST, LNE-LNHB, France)

14:35-15:20 **DDEP Evaluation Software**
Using SAISINUC, BRICC, EMISSION, etc. Practical nuclear decay data evaluation works. *Discussion, Questions/Answers session*

15:20-15:40 ***Coffee Break***

15:40-15:50 **Current status of DDEP evaluations**
Dr. Marie-Martine Bé (CEA/LIST, LNE-LNHB, France)

15:50-16:30 **Aspects of nuclear decay data evaluation in DDEP**
Evaluations planned/ongoing, future plans, evaluation principles, software tools, the necessity to update the existing evaluations, guidelines for the evaluations reviewers etc. *Discussion*

Wednesday, October 8, 2014

09:00-12:00 **Visit to IFIN-HH, Radioisotopes and Radiation Metrology Department: Radionuclide Metrology Laboratory, Radiopharmaceuticals Research Centre and other laboratories**

12:00-13:30 ***Lunch Break***

13:30-14:30 **Round Table:**
DDEP - present status and future developments; comments of the participants.
Discussion

End of the Workshop

List of participants
(alphabetical order)

Andrei ANTOHE, *IFIN-HH, Magurele, Romania*
Marie-Martine BÉ, *CEA/LIST, LNE-LNHB, Saclay, France*
Cristina BORDEANU, *IFIN-HH, Magurele, Romania*
Thierry BRANGER, *CEA/LIST, LNE-LNHB, Saclay, France*
Adrian Florinel BUCŞA, *ICN, Pitesti, Romania*
Paraskevi DIMITRIOU, *IAEA, Vienna, Austria*
Raluca DINCĂ, *RATEN, Magurele, Romania*
Christophe DULIEU, *CEA/LIST, LNE-LNHB, Saclay, France*
Tomasz DZIEL, *POLATOM, Otwock, Poland*
Xiaolong HUANG, *CIAE/CNDC, Beijing, China*
Simona ILIE, *University of Bucharest, Faculty of Physics (master's student)*
Mihail-Răzvan IOAN, *IFIN-HH, Magurele, Romania*
Mark A. KELLETT, *CEA/LIST, LNE-LNHB, Saclay, France*
Aurelian LUCA, *IFIN-HH, Magurele, Romania*
Xavier MOUGEOT, *CEA/LIST, LNE-LNHB, Saclay, France*
Beatris Luminița NEACŞU, *IFIN-HH, Magurele, Romania*
Alexandru NEGREȚ, *IFIN-HH, Magurele, Romania*
Ninel NICA, *Texas A&M University, USA*
Dana NICULAE, *IFIN-HH, Magurele, Romania*
Maria SAHAGIA, *IFIN-HH, Magurele, Romania*
Doru STÂNGĂ, *IFIN-HH, Magurele, Romania*
Zoltan SZUCS, *ATOMKI, Debrecen, Hungary*
Zbigniew TYMIŃSKI, *POLATOM, Otwock, Poland*
Nicolae Victor ZAMFIR, *IFIN-HH, Magurele, Romania*

Improvements of Decay Data in RW and NORM materials

M.M. Bé[1], and all the participants
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Keywords: decay data, Sm-151, I-129, U-238 series, U-235 series, La-138

The aims of these studies are:

- To determine the half-life of nuclides which appear in Radiative Wastes, such as Sm-151, I-129.
- To improve the quality of the currently available decay data of some of the naturally occurring radionuclides such as the ^{238}U and the ^{235}U chains. For example, the alpha emission intensities in the ^{226}Ra decay have only been measured twice in the past and the results are discrepant from each other and with the values derived from the decay scheme balance. Therefore, new measurements are needed.
- To analyse the difficulties which arise in the measurement of NORM samples, Moreover, the 185.7 keV gamma-ray in the ^{235}U decay overlaps with the 186.2 keV gamma-ray of the ^{226}Ra decay and complicates the determination of the amount of ^{226}Ra in a sample.
- To increase the knowledge of the intensities of the photons and electrons emitted in the lanthanum 138 rare earth element decay. Lanthanum-based scintillators are radiation detectors attracting great interest in various applications due to their good energy resolution at ambient temperature. However, they suffer significantly from intrinsic radioactivity which has two origins: the presence of the naturally occurring isotope ^{138}La.

This presentation will present the actions carried out in the framework of two European projects: MetroRWM and MetroNORM.

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Presentation of the results obtained in the joint research project IFA Romania – CEA France no. C2-05/2012

Thierry Branger[1]*, Carole Fréchou[1], Christophe Bobin[1], Philippe Cassette[1], Cheick Thiam[1], Marie-Christine Lépy[1], Laurine Brondeau[1], Marie-Martine Bé[1], Valérie Lourenço[1], Didier Lacour[1], Isabelle Le Garrérès[1], Aurelian Luca[2], Maria Sahagia[2], Andrei Antohe[2], Mihail-Răzvan Ioan[2], Beatris Luminiţa Neacşu[2], Constantin Ivan[2]

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In the framework of the joint research project IFA Romania – CEA France no. C2-05/2012 between IFIN-HH and LNHB, two studies were carried on at LNHB for ^{82}Sr/^{82}Rb and ^{177}Lu. The objectives were to have an international traceability to the SIR (Système International de Référence) of BIPM and to ensure the standardization of hospitals equipments for the measurements of these radionuclides. The main operations performed were: radionuclidic impurities (beta and gamma) check, absolute activity measurements by the 4πβ(PC)-γ coincidence method and relative activity measurements (ionization chambers). This presentation details the operations which were carried out at LNHB.

The research performed at IFIN-HH, Radionuclide Metrology Laboratory (RML), in the framework of the above mentioned project is described, too. The most important part consisted in the metrological study of two radionuclides with applications in nuclear medicine: ^{177}Lu and ^{186}Re. The main operations performed were: absolute activity standardization of the radioactive solutions using the 4πβ(PC)-γ coincidence method; activity measurements, radionuclidic impurity check and photon emission intensity determination using gamma- and X-ray spectrometry; establishment of the equivalence degree of the Romanian activity standard through the CCRI(II)-K2.Lu-177 (2009) and of the SIR, BIPM RI(II)-K1.Lu-177 (2013) key comparisons; calibration of the CENTRONIC IG12/20A ionization chamber for various types of recipients, to be used both for the measurement of the radiopharmaceutical solution and organ/tissues biodistribution; accurate half-life measurements using the ionization chamber; study of the nuclear decay data.

The joint research project IFA Romania – CEA France no. C2-05/2012 will continue until the end of February 2015.

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NUCLEAR STRUCTURE AND DECAY DATA AT THE IAEA NUCLEAR DATA SECTION

Paraskevi Dimitriou*
Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria

The NDS/IAEA is committed to the development, compilation, evaluation and dissemination of nuclear data through a number of projects, training activities and services. In this paper, we shall present the main activities of NDS/IAEA related to nuclear structure and decay data.

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TIPS AND TRICKS WITH SAISINUC

Christophe Dulieu*, Mark A. Kellett
CEA/LIST, LNE-LNHB, CE Saclay, 91191 Gif sur Yvette, France

The DDEP evaluation software tool, SAISINUC, developed at LNE-LNHB, is used for the preparation of evaluations. A number of little known features will be presented, in order to help evaluators in the preparation of their data files, including:

- Automatic import of reference lists
- Export of reference lists
- Importation of levels from an ENSDF file
- Updated mass tables, Q-values

Further developments to the software are planned, and details will be given, e.g. better handling of references.

Additionally, information will be presented on how the evaluator can be kept up to date with new evaluations, through an RSS feed, and on where the latest software can be downloaded.

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EVALUATION OF THE 1077 KEV γ-RAY EMISSION PROBABILITY FROM ^{68}Ga DECAY

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^{68}Ga decays to the excited states of ^{68}Zn through the electron capture decay mode. New recommended values for the emission probability of 1077 keV γ-ray given by the ENSDF and DDEP databases all use data from absolute measurements. In 2011, JIANG Li-Yang deduced a new value for 1077 keV γ-ray emission probability by measuring the ^{69}Ga(n,2n)^{68}Ga reaction cross section. The new value is about 20 % lower than values obtained from previous absolute measurements and evaluations. In this paper, the discrepancies among the measurements and evaluations are analyzed carefully and the new values are re-recommended. Our recommended value for the emission probability of 1077 keV γ-ray is 3.0±0.2 %.

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EVALUATION OF NUCLEAR DECAY DATA FROM THE DECAY OF ^{177}Lu AND ^{186}Re

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The results of recent measurements performed at IFIN-HH, within the framework of the joint research project IFA Romania – CEA France no. C2-05/2012, are analysed. The half-life and photon emission intensities in the decays of ^{177}Lu and ^{186}Re were determined and are compared with other published results and the most recent DDEP evaluations of these two radionuclides. The updating of the two nuclear decay data evaluations, which is in progress, is also discussed.

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EXPERIMENTAL DETERMINATION OF NUCLEAR DECAY DATA FROM THE DECAY OF ^{177}Lu AND ^{186}Re

Aurelian Luca*, Maria Sahagia, Andrei Antohe, Mihail-Răzvan Ioan
Horia Hulubei National Institute of Physics and Nuclear Engineering, IFIN-HH, Magurele, Ilfov, RO-077125, Romania

In the framework of the joint research project IFA Romania – CEA France no. C2-05/2012 between IFIN-HH and LNHB, the experimental determination of nuclear decay data in the decays of ^{177}Lu and ^{186}Re was performed at IFIN-HH, Radionuclide Metrology Laboratory (RML), during 2013-2014.

The absolute activity standardization by the method $4\pi\beta$(PC)-γ coincidence allowed the experimental determination of absolute photon emission intensities, using high resolution gamma-ray spectrometry. Several corrections applied are presented.

The half-life values of the two radionuclides were measured using a CENTRONIC IG12/20A ionization chamber. In the case of ^{177}Lu, the impurity ^{177m}Lu (with the half-life, $T_{1/2}$ = (160.44 ± 0.06) days, according to the evaluation of F.G. Kondev, Nucl. Data Sheets 98, 801 (2003)) was detected in the radioactive solution, and measured using two different methods. The impurity contribution increases in time, and a corresponding correction must be applied to the ^{177}Lu half-life experimental result.

The final results are presented and discussed. All the nuclear decay data determined in this study will be disseminated and made available for future nuclear decay data evaluations.

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EXPERIMENTAL STUDY OF BETA SPECTRA USING A SEMICONDUCTOR SILICON DETECTOR

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A new beta spectrometer, based on a silicon PIPS detector operating at liquid nitrogen temperature under ultra-high-vacuum, will be presented. The beta spectra from ^{14}C, ^{151}Sm and ^{99}Tc decays were measured using this setup. Our method of source preparation, using thin VYNS films and electro-sprayed latex microspheres, will be shown. The precise modeling of the whole setup with Geant4, including the source geometry, will be presented. Excellent agreement is found above 15 keV compared to the simulated spectra, close to the experimental energy threshold of 12 keV. The unfolding process of the measured spectra in order to extract experimental shape factors will be detailed.

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PRECISE MEASUREMENT OF THE K-SHELL INTERNAL CONVERSION COEFFICIENT FOR THE 88.3-KEV M4 TRANSITION IN ^{127}Te

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In a research program aimed at testing calculated internal-conversion coefficients (ICCs), we have made precise measurements of α_K values for transitions in five nuclei, ^{197}Pt, ^{193}Ir, ^{137}Ba, ^{134}Cs and ^{119}Sn, which span a wide range of *A* and *Z* values. In completing this series we also measured the 88.3-keV *M4* transition in ^{127}Te obtaining the preliminary result 489(7). In this last measurement as in all the other cases, the results strongly agree with the Dirac-Fock calculations in which the final-state electron wave function has been computed using a potential that includes the atomic vacancy created by the internal-conversion process, and disagree with the calculations in which the vacancy is ignored. Based on our results both the DDEP and ENSDF data communities adopted the calculations including the atomic vacancy in their standard procedures.

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RADIOPHARMACEUTICALS RESEARCH CENTRE – A NEW FACILITY AT HORIA HULUBEI NATIONAL INSTITUTE FOR PHYSICS AND NUCLEAR ENGINEERING

Dana Niculae*, Liviu Craciun, Ioan Ursu
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The commissioning of CCR (Radiopharmaceuticals Research Centre) at IFIN-HH is presented. CCR is a state-of-the-art facility based on a cyclotron and radiochemistry, dedicated to radioisotopes studies and preparation of radiopharmaceuticals for clinical use. Its unique characteristics and performance open new perspectives for significant future achievements in these multidisciplinary areas.

The extraordinary evolution in medical imaging and the foreseen breakthrough in targeted therapy have raised the interest worldwide and brought a tremendous development in producing a wealth of radiopharmaceuticals, specific radiotracers and innovative targeting therapeutic agents.

In line with these developments and exploiting the significant achievements of IFIN-HH in the past decades in radiophamaceutical research and production and seeking also to respond to a particularly critical societal need, the absence of a national source for PET isotopes, IFIN-HH has engaged first major projects for PET isotopes in Romania and finally in establishing a state of the art Centre, dedicated to the study of radiopharmaceuticals, both for medical imaging and targeted therapy, in view of their future implementation in medical practice.

Remaining committed to its steady goals of developing a sound in-house capability, in order to stay in the forefront of the current nuclear science and technology and to widening the impact of nuclear technologies on industry, other business areas, as well as on the society at large, IFIN-HH has implemented during 2009-2014 an investment project entitled "Infrastructure development for frontier research in nuclear physics and related fields".

As part of this wider development plan, the CCR facility was thought to bring an impetus to relevant and valuable interdisciplinary scientific research in life sciences. The project foresaw to build more than 1330 m² state-of-the-art centre comprising one of the newest generation of cyclotrons (TR19) and a highly specialized radiopharmaceutical facility.

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RECENT WORK AND RESULTS OF THE RADIONUCLIDE METROLOGY LABORATORY FROM IFIN-HH

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This paper refers at the Radionuclide Metrology Laboratory (RML) work accomplished since the last scientific event "2008 Workshop of the Decay Data Evaluation Project" (DDEP-2008), consisting in training sessions for the nuclear decay data evaluators, Bucharest (Romania), during the period 12-14 May, 2008, when the main author presented the activities of the RML from IFIN-HH.

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Simultaneous production of ^{55}Co, ^{57}Ni and ^{64}Cu for PET imaging

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The cobalt, nickel and copper are well known as essential trace elements in the biosphere by the metallo-organic compounds. Their importance in blood system and chelate bonds to the bioactive macro-peptides is evident. The applications of positron emitting isotopes of these elements in nuclear medicine are still in the focus of the scientific interest. The optimal production of these isotopes in quality of high specific activity is different [1-3]. The simultaneous production of ^{55}Co, ^{57}Ni and ^{64}Cu from ^{nat}Ni by proton beam of cyclotron can be preferable due to the cheap target material and the parallel running nuclear reactions, such as ^{58}Ni(p,α)^{55}Co, ^{58}Ni(p,2n)^{57}Cu→^{57}Ni and ^{64}Ni(p,n)^{64}Cu.

The strength of complexation of metal ions with chloride ions depends of the concentration of chloride ion. This is the theoretical background for separation of different transition metal ions by ion-chromatography [4].

The natural Ni was used for the irradiation (vertical proton beam line, 15 MeV, 20 mAs). In case of Ni target the separation was carried out in 5 mol dm^{-3} HCl media, when the Ni^{2+} ions went through the anion-exchanger column as effluent and after that the ^{64}Cu was washed out by water. However the ^{55}Co radioisotope originated from the side reaction was also separated when the Co^{2+} also eluted just after the Ni^{2+} ions. The separation of ^{55}Co and ^{57}Ni was also completed as it is showed in Table 1. The difference of magnitude was detected between the dose rate of these isotopes, where the Co radioisotope has the most high dose rate and the smallest was the ^{57}Ni.

The separation by ion exchange method is a powerful tool to get the stock solution of these positron emitter radioisotopes for labelling procedure in nuclear medicine. The γ-ray spectra of the fractions prove the purity of the radioactive isotopes.

This paper suggests a cheap production way for three positron emitter radioisotopes as the famous ^{64}Cu as well as the ^{55}Co, ^{57}Ni. Only one radiochemical separation needs for all radioisotopes in range of few mCi of radioactivity, which would be eligible for the small animal PET study.

Table 1: Dose rate of the positron emitters in the eluted fractions, where the „A" is the 5 mol dm^{-3} HCL effluent and the „W" is the water effluent

A1	A2	A3	A4	A5	A6	W1	W2
22	22	24	3700	60	0	0	477
^{57}Ni	^{57}Ni	^{57}Ni ^{55}Co	^{55}Co	^{55}Co	-	-	^{64}Cu

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